



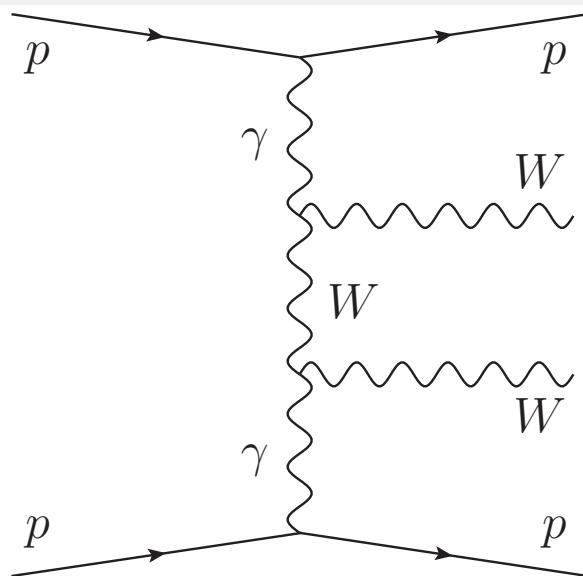
Anomalous coupling studies

*Hervé Grabas – Christophe Royon – Oldrich Kepka – Emilien Chapon
– Rafał Staszewski*

Anomalous $WW\gamma$ $WW\gamma\gamma$ $ZZ\gamma\gamma$ coupling in γ induced processes²

- Leptonic decay study done by C.Royon, O. Kepka, E. Chapon, R. Staszewski, A Dechambre.
 - E. Chapon, O. Kepka, C. Royon, arXiv:08h08.0322, Phys. Rev. D78 (2008) 073005; arXiv: 908.1061; arXiv:0912.5161 Phys. Rev. D81 (2010) 074003
- Semi-leptonic decay study in progress using framework developed for the leptonic decay.
- $\gamma\gamma \rightarrow \gamma\gamma$ implementation is next and further anomalous coupling studies involving Higgs and dimension 8 operators.

WW production at the LHC



- Study of the process $p p \rightarrow p p W W$
- **Clean process:** W in central detector, intact protons detected far away (see C. Royon talk on AFP).
- **Exclusive W pair production via photon exchange:** QED process with cross section perfectly known.
- **Two steps:** SM observation of WW , anomalous coupling.
- **Rich $\gamma\gamma$ physics at LHC:** see E. Chapon, O. Kepka, C. Royon, Phys. Rev. D78 (2008) 073005; arXiv:0912.5161 accepted by Phys. Rev. D; T J. De Favereau et al., arXiv: 0908.2020.

Quartic anomalous gauge coupling

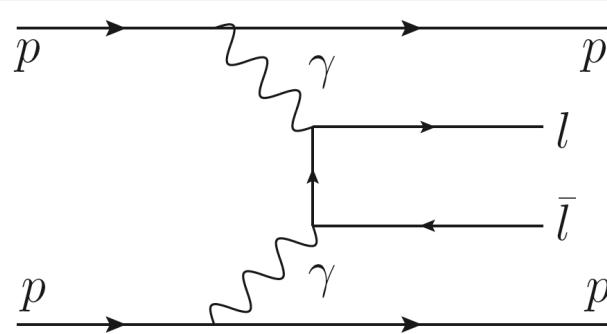
- Quartic gauge anomalous WW and ZZ couplings parameterized by a^W_0 , a^Z_0 , a^W_C , a^Z_C

$$\begin{aligned}\mathcal{L}_6^0 &\sim \frac{-e^2}{8} \frac{\textcolor{red}{a}_0^W}{\Lambda^2} F_{\mu\nu} F^{\mu\nu} W^{+\alpha} W^{-\alpha} - \frac{e^2}{16 \cos^2(\theta_W)} \frac{\textcolor{red}{a}_0^Z}{\Lambda^2} F_{\mu\nu} F^{\mu\nu} Z^\alpha Z_\alpha \\ \mathcal{L}_6^C &\sim \frac{-e^2}{16} \frac{\textcolor{red}{a}_C^W}{\Lambda^2} F_{\mu\alpha} F^{\mu\beta} (W^{+\alpha} W^-_\beta + W^{-\alpha} W^+_\beta) \\ &\quad - \frac{e^2}{16 \cos^2(\theta_W)} \frac{\textcolor{red}{a}_C^Z}{\Lambda^2} F_{\mu\alpha} F^{\mu\beta} Z^\alpha Z_\beta\end{aligned}$$

- Anomalous parameters equal to 0 for SM
- Non zero anomalous couplings motivated by Higgsless and extra dimension models (under study: Christophe Grojean et al.)
- Best limits from LEP, OPAL (Phys. Rev. D 70 (2004) 032005) of the order of 0.02-0.04, for instance $-0.02 < a^W_0 < 0.02 \text{ GeV}^{-2}$
- Allows to probe the values predicted by Higgsless/extradimension models (C. Grojean, J. Wells et al.)
- Dimension 6 operators ! violation of unitarity at high energies

WW production – Leptonic decay

- **Signal:** Leptonic decay signals of WW and ZZ . The protons are tagged in the forward detector.
- **Backgrounds considered:**
 - Non diffractive WW production: large energy flow in forward region, removed by requesting tagged protons.
 - Two photons dileptons: back-to-back leptons, small cross-section for high p_T leptons.



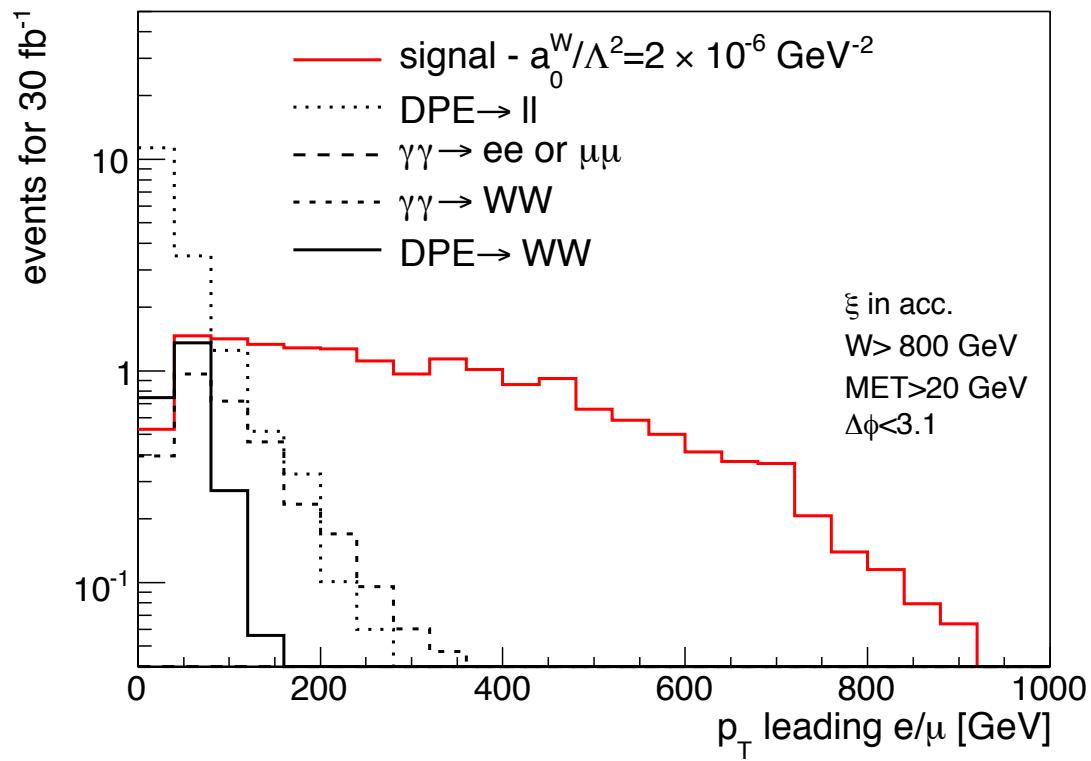
- **Lepton production via double pomeron exchange:** activity in the forward region due to pomeron remnants, removed by missing E_T cut.
- **WW via double pomeron exchange:** removed by cut on high diffractive mass.

Forward Physics Monte Carlo (FPMC)

- FPMC (Forward Physics Monte Carlo): implementation of all diffractive/photon induced processes
- List of processes
 - two-photon exchange
 - single diffraction
 - double pomeron exchange
 - central exclusive production
- Inclusive diffraction: Use of diffractive PDFs measured at HERA, with a survival probability of 0.03 applied for LHC
- Survival probability for photon exchange events: 0.9
- Central exclusive production: Higgs, jets... for Khoze Martin Ryskin or Dechambre Cudell models as an example; Szczerba et al. model to be implemented
- FPMC manual: see M. Boonekamp, A. Dechambre, O. Kepka, V. Juranek, C. Royon, R. Staszewski, M. Rangel, ArXiv:1102.2531, code to be public soon
- Output of FPMC generator interfaced with the fast simulation of the ATLAS detector in the standalone ATLFast++ package

Quartic anomalous gauge couplings

- Distribution of the leading lepton p_T after all cuts (proton tagged, missing E_T , diffractive mass, $\Delta\Phi$).



Quartic anomalous gauge couplings

Background events for 30 fb^{-1}

cut / process	$\gamma\gamma \rightarrow ll$	$\gamma\gamma \rightarrow WW$	DPE $\rightarrow ll$	DPE $\rightarrow WW$
$p_T^{lep1,2} > 10 \text{ GeV}$	50619	99	18464	8.8
$0.0015 < \xi < 0.15$	21058	89	11712	6.0
$E_T > 20 \text{ GeV}$	14.9	77	36	4.7
$W > 800 \text{ GeV}$	0.42	3.2	16	2.5
$M_{ll} \notin [80, 100]$	0.42	3.2	13	2.5
$\Delta\phi < 3.13$	0.10	3.2	12	2.5
$p_T^{lep1} > 160 \text{ GeV}$	0	0.69	0.20	0.024

Signal events for 30 fb^{-1}

cut / couplings (with f.f.)	$ a_0^W/\Lambda^2 = 5.4 \cdot 10^{-6}$	$ a_C^W/\Lambda^2 = 20 \cdot 10^{-6}$
$p_T^{lep1,2} > 10 \text{ GeV}$	202	200
$0.0015 < \xi < 0.15$	116	119
$E_T > 20 \text{ GeV}$	104	107
$W > 800 \text{ GeV}$	24	23
$M_{ll} \notin [80, 100]$	24	23
$\Delta\phi < 3.13$	24	22
$p_T^{lep1} > 160 \text{ GeV}$	17	16

Reach at LHC

- Reach at high luminosity on quartic anomalous coupling

Couplings	OPAL limits [GeV ⁻²]	Sensitivity @ $\mathcal{L} = 30$ (200) fb ⁻¹	
		5 σ	95% CL
a_0^W / Λ^2	[-0.020, 0.020]	$5.4 \cdot 10^{-6}$ ($2.7 \cdot 10^{-6}$)	$2.6 \cdot 10^{-6}$ ($1.4 \cdot 10^{-6}$)
a_C^W / Λ^2	[-0.052, 0.037]	$2.0 \cdot 10^{-5}$ ($9.6 \cdot 10^{-6}$)	$9.4 \cdot 10^{-6}$ ($5.2 \cdot 10^{-6}$)
a_0^Z / Λ^2	[-0.007, 0.023]	$1.4 \cdot 10^{-5}$ ($5.5 \cdot 10^{-6}$)	$6.4 \cdot 10^{-6}$ ($2.5 \cdot 10^{-6}$)
a_C^Z / Λ^2	[-0.029, 0.029]	$5.2 \cdot 10^{-5}$ ($2.0 \cdot 10^{-5}$)	$2.4 \cdot 10^{-5}$ ($9.2 \cdot 10^{-6}$)

- Improvement of LEP sensitivity by more than 4 orders of magnitude with 30/200 fb⁻¹ at LHC.
- Reaches the values predicted by Higgsless/extradimension models
- Without AFP: these values cannot be reached, only gain of two order of magnitude by studying $p\bar{p} - \rightarrow \ell\nu\gamma\gamma$, see ArXiv 0907.5299

WW production – Can we improve sensitivity: Semi-leptonic decay

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- **Signal:** Semi-leptonic decay signals of WW and ZZ . The protons are tagged in the forward detector.
- **Backgrounds considered:**
 - Inclusive $W+\chi$ production
 - DPE W production
 - SM photon exchange WW production.
 - **Inclusive ttbar pair production -> $W+\chi$ decay Pile up**
- Cut scheme foreseen to be similar. + cut on jets and cut on number of tracks fitted to vertex (to get rid of pile up).
- Study ongoing..

Conclusion

- ATLAS and CMS project to install additional forward proton detectors
- Improvement of LEP (OPAL) sensitivity by four orders of magnitude with 30-200 fb⁻¹: allows to probe extradim/higgsless models with an unprecedented precision, looks impossible without forward detectors
- Project under evalution in ATLAS (AFP), technical proposal submitted to ATLAS
- Semi-leptonic studies in progress and additional anomalous coupling studies are also in progress.